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GRAIN QUALITY IN ORGANIC AND ECOLOGICAL CROPPING SYSTEMS

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Abstract

Ecological cropping includes combination of different crops at the same field and application of organic and mineral fertilizers, according to plant requirements. Organic cropping includes application of allowed organic fertilizers.
Trial was conducted during 2012. In ecological production maize and soybean were grown as: single crops (SC), in alternating rows (AR) and alternating strips (3 rows of each crop - AS). Fertilization regimes included: urea, Ofert (organic fertilizer), Uniker (microbiological fertilizer) and control. Organic production in trial included spelt, soybean and maize. Fertilization regimes were: DCM EKO-MIX 1 (F1), DIX 10 N (F2) and control. After harvest, grain yield, mass of 1000 grains, and content of phenolics, glutathione, phytate and β-carotene were determined in grain.
In ecological production the highest yields and 1000 grain weight were obtained in Uniker treatment, as well as with AR cropping in both crops, with two times higher values in soybean, in relation to control. Generally, soybean grain had higher levels of phytate, phenolics and β-carotene, compared to maize. In organic production differences in yield parameters were insignificant. Uniker show the highest impact on phytate and β-carotene accumulation in grain of both crops in ecological production, and the same trend was noticed in F1 treatment in organic production. The content of phenolics and glutathione varied among fertilization treatments, but the highest values were obtained in AR cropping. Lower level of phytate and higher level of β-carotene achieved in crops from organic production indicated higher nutritional quality of crops produced in this system.
Key words: antioxidants, cropping systems, fertilization, grain, composition

Introduction

Ecological agriculture applies the strengths of natural ecosystems in agro-ecosystems, to produce food and fiber. The overall strategies include growing of healthy plants with good defense capabilities, stressing pests and enhancing populations of beneficial organisms (Magdoff, 2007). From that point, Ecological agriculture includes combination of different crops at the same field and application of organic fertilizers, enabling better utilization of space and nutrients, with minimal inputs. On the other hand, organic agriculture means production of high quality food or raw material with maintaining the soil quality. It is based on controlled input of allowed agrochemicals that are mainly natural products, like plant extracts, fertilizers originating from decomposed organic products or manure from organic cattle production.
Cropping systems aimed for high quality food production include all available measures that increase nutrients favourable for human health and growing of improved genotypes. For example, red maize provides 20% more protein than white or yellow maize. It is rich in anthocyanins and flavonoids, which are antioxidants (Žilić et al 2011a). Black soybean also contains two times more phenolics than yellow grain genotypes (Žilić et al., 2011b). Ruibal-Mendieta et al. (2005) emphasized higher nutritional value of spelt (*Triticum aestivum ssp. spelta*) than common wheat, with high content of mineral nutrients and low content of gluten and phytic acid. It is also rich in phenolics (Gawlik-Dziki et al., 2012).

One of the most important components for phosphorus storage is phytate (Schlemmer et al., 2009). Phytate is antinutritive, due to its indigestibility for monogastric organisms, but at the sime time, has positive role as an antioxidant and anticancerogenic agent. Malenčić et al. (2007) underlined phenolics as bearers of antioxidative activity in soybean seeds, since the seeds with low phenolic's content have poor antioxidative activity, too. One of the most important antioxidative and nutritive factor is glutathione, which participate in signalling and stress prevention in plants (Foyer and Noctor, 2005). Grodstein et al. (2007) emphasized antioxidative function of β-carotene.

The aim of experiment was to compare ecological and organic production from the point of potential to improve grain quality of maize, soybean and spelt, based on content of antioxidants.

Material and methods

Experiment with intercropping in ecological production was conducted during 2012, with varieties of red grain maize (variety Rumenka) and black grain soybean (variety Dukat). Crops were grown as: single crop (SC), alternating rows of both crops (AR) and alternating strips (3 rows of each species - AS). Fertilization regimes included incorporation of: Uniker (microbiological fertilizer applied 11 l/ha), Ofert (organic fertilizer applied 3 t/ha), urea (applied 163 kg/ha) and control (without fertilization).

Experiment with organic production included three fields. In the first field spelt wheat (variety Nirvana) was seeded in October of 2011. Second field included maize variety Rumenka with application of 2 organic fertilizers: F1 (DCM EKO-MIX 1 (N:P:K=9:3:3, 65% organic matter) and F2 (DIX 10 N (N:P:K=10:3:3, 72.5% organic matter) in amount of 500 kg ha^{-1}, as well as control (without fertilization). Third field was seeded with soybean (variety Lidija). Spelt and soybean fields didn't include any treatment.

Table 1. Amount of nutrients, incorporated with different fertilization regimes

Fertilizer treatment	Fertilizer amount	Nutrient amount (kg/ha)		
		N	P	K
Uniker	11 l/ha	Microbiological fertilizer		
Ofert	3 t/ha	66	144	84
Urea	163 kg/ha	75	-	-
DCM EKO-MIX 1	500 kg/ha	45	15	15
DIX 10 N	500 kg/ha	50	15	15

Both experiments were set up in rain-fed conditions on chernozem soil type. After harvest, grain yield, mass of 1000 grains, and content of antioxidants (phytic acid (PA), β-carotene, phenolics and total glutathione (GSH)) were determined in grains. PA was determined by the method of Dragičevic et al. (2011); B-carotene was determined according to AACC (1995) procedure; phenolics were determined by the method of Simić et al. (2004) and GSH by the method of Sari-Gorla et al. (1993). The obtained results were presented with standard deviation (SD).

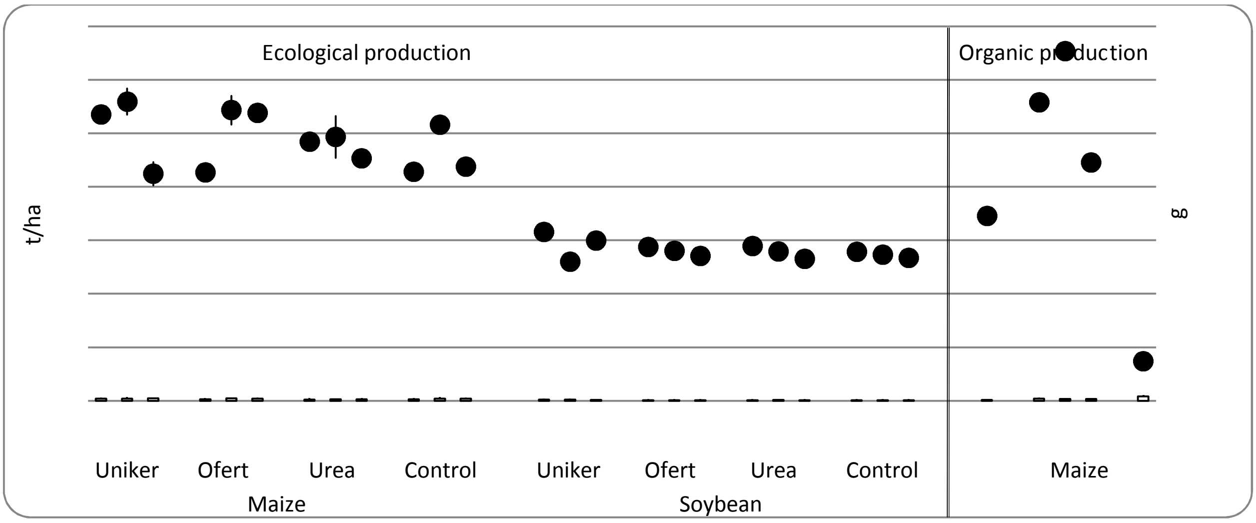
Meteorological conditions during vegetative period of 2012 (Table 1) indicated unequal distribution of precipitation, with the lowest value in August accompanied with high average temperatures in July and August.

Table 1. Meteorological conditions during vegetative period of 2012

Month	IV	V	VI	VII	VIII	IX	Aver./Σ
T average (°C)	14.45	17.90	24.56	27.08	26.21	22.14	22.05
Σ precipitation (mm)	66.7	127.5	13.9	39.4	4	31.4	47.15

Results and discussion

Our results in ecological production experiment underlined Uniker and AR as treatments with the highest achieved grain yield and 1000 grain weight of both crops, maize and soybean (Figure 1). Unfavourable meteorological conditions were particularly reflected on low soybean yield, irrespective to production type, where Uniker and urea in ecological, as well as in organic production induced negligible higher yields. On the other hand, ecological production brings upon increase in maize yield in Ofert treatment in AR (about 33% higher in regard to the same treatment in SC), while differences between treatments in organic production were minor. Undie et al. (2012) and Verdelli et al. (2012) also underlined that maize and soybean intercrops were more productive than sole crops. The differences between ecological and organic production in maize yield were about 2%. This corresponds with results of Messmer et al. (2009) who also reported small differences between grain yields in organic and conventional farming. The highest grain yield was attained with spelt, which avoided unfavourable conditions during grain filling period of maize and soybean (July, August).



Fugure 1. The influence of applied cropping systems (ecological and organic) and treatments on grain yield (☐) and 1000 grains weight (✹); SC – single crop;, AR – alternating rows; AS – alternating strips; Cont. – control; F1 - DCM EKO-MIX 1; F2 - DIX 10 N; Mean value ± SD.

Although phytic acid is antioxidant its low content in grain is desirable, since it obstructs absorption of mineral nutrients (Schlemmer et al., 2009). It is obvious that soybean has several times higher PA content in grain, compared to maize and particularly to spelt (Figure 2). In present conditions of ecological production, the lowest PA content was mainly noticed in maize and soybean grain at AR treatment, while the Uniker showed tendency to increase PA in grains, probaly due to phosphorus nutrition enabled by different circumstances in rhizosphere (Zhang and Li, 2003). It was important to underline that average PA content was about 41% lower in maize grain from organic, compared to ecological production. The lowest PA content was observed in spelt grain, what could be its advantage as basis in foods with improved mineral availability (Ruibal-Mendieta et al., 2005, Queiroz et al., 2011).

Similar with PA, the highest β-carotene content was observed in maize and soybean grain from Uniker treatment, grown as single crop (Figure 2). It is also obvious that soybean grain has about 4 times higher β-carotene content than maize in ecological, while in organic production this difference was lower. F1 treatment increased PA and β-carotene contents in maize in organic production. Menkir and Mazya-Dixon (2004) noticed low variations in β-carotene content in grain under the influence of environment, while the genotype was main source of variation. The lowest β-carotene content was in spelt grain.

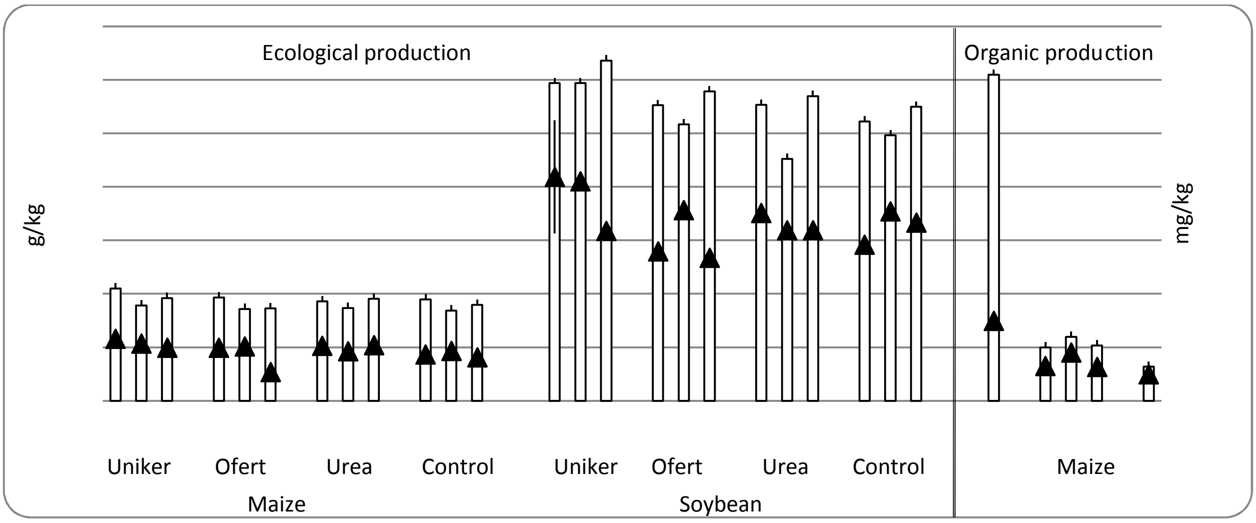


Figure 2. The influence of applied cropping systems (ecological and organic) and treatments on contents of phytic acid (☐) and β-carotene (▲);SC – single crop;, AR – alternating rows; AS – alternating strips; Cont. – control; F1 - DCM EKO-MIX 1; F2 - DIX 10 N; Mean value ± SD.

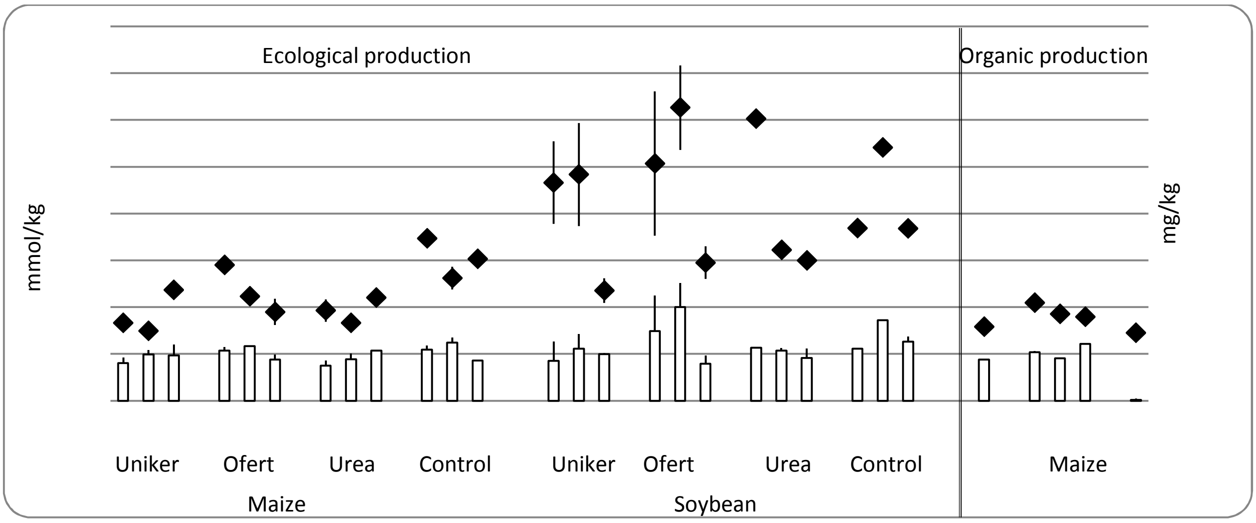


Figure 3. The influence of applied cropping systems (ecological and organic) and treatments on contents of total glutathione (☐) and phenolics (◆);SC – single crop;, AR – alternating rows; AS – alternating strips; Cont. – control; F1 - DCM EKO-MIX 1; F2 - DIX 10 N; Mean value ± SD.

GSH is protein with important role in cell signalling and protection against oxidative attack (Foyer and Noctor, 2005). Ofert and AR were the treatments in ecological production that increased its content in maize and soybean grain (Figure 3), irrespective to its higher variations present in soybean. In organic production, GSH content was increased in F2 treatment. It is interesting that the lowest GSH content was obtained in spelt grain.

Phenolics are secondary metabolites, involved in protection from free radicals and pests (Santiag and Malvar, 2010). Their content varied the most (57-62%) among examined antioxidants (PA 19-29%; β-carotene 36-54%; GSH 39-57%) in grains from ecological production. The highest content of phenolics was observed in maize grain in control in CS treatment and in soybean grain in Ofert in AR treatment. Several times higher phenolic content was found in soybean from ecological production, what could be attributed to its black grain. That could be important, since Malenčic et al. (2007) underlined that phenolics are bearers of antioxidative activity in soybean seeds. Relatively balanced phenolic content was in all three crops in organic production, with the highest level noticed in maize in control, while the lowest value was found in spelt. This value, obtained in spelt grain is in accordance with results gained by Gawlik-Dziki and Dziki (2012).

Conclusion

Based on obtained results from preliminary research, it could be concluded that examined production models could increase nutritional value of maize and soybean grain. Alternating rows, as intercropping system of ecological production increased mainly grain yield and content of antioxidants (β-carotene, GSH and phenolics), as well as decreased PA level in maize and soybean grain. Both fertilizers, Uniker and Ofert improved yield and quality of produced grains, stressing Ofert as treatment which increased GSH and phenolics and reduced PA level. On the other hand, applied fertilizers in organic production didn’t show expected results in maize yield and grain quality, while spelt was emphasized as low PA and moderate in phenolics grain.

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